ONR LONDON REPORT

R-11-77

(12) 2

OFFICE OF NAVAL RESEARCH

BRANCH OFFICE LONDON ENGLAND

(6) INFORMATION THEORY IN HUNGARY.

(10) NELSON M. BLACHMAN

(11) 29 NOV[illegible]77 (12) 15P.

(14) ONRL-R-11-77

UNITED STATES OF AMERICA

This document is issued primarily for the information of U.S. Government scientific personnel and contractors. It is not considered part of the scientific literature and should not be cited as such.

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

265 000 JOB

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER R-11-77	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INFORMATION THEORY IN HUNGARY		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) NELSON M. BLACHMAN		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Naval Research Branch Office London Box 39, FPO New York 09510		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 29 November 77 13. NUMBER OF PAGES 13
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hungary	Communication Theory
Information theory	Mathematics
Statistics	Higher education

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report discusses the work of the Mathematical Institute of the Hungarian Academy of Sciences with emphasis on its Information Theory and Statistics Groups. The work of the Institute for Communication Electronics of the Technical University of Budapest is also mentioned together with a general picture of the Faculty of Electrical Engineering. Some remarks are included concerning information-theoretical research elsewhere in Hungary.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

INFORMATION THEORY IN HUNGARY

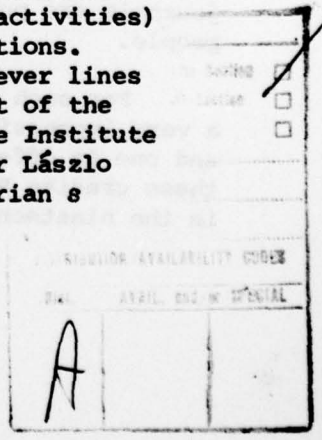
In Hungary research in information theory and statistical communication theory is carried out principally at four institutions: The Telecommunications Research Institute (TKI) (called "Taki") Gábor Áron út 65 just west of Törökvész út; the Communication Electronics Institute of the Technical University of Budapest at Stoczek utca 2 (tel. 450-300); the Fine Mechanical Works (FMV) at Fehér út 10 (tel. 836-775); and the Mathematical Institute of the Hungarian Academy of Sciences (Magyar Tudományos Akadémia Matematikai Kutató Intézete), Reáltanoda utca 13-15 (tel. 182-875).

Since the time of Josef Jauch's visit a decade ago to this last Institute (ONRL-R-56-67), living conditions in Hungary have improved considerably, but it is still a largely agrarian country, and there is still a secret if much less active police force. Hungarians nonetheless are enjoying much more contact with the West than previously, both through visits from abroad and visits to other countries.

Except for pocket calculators (whose importation is forbidden in order to protect a domestic computer industry that does not yet appear to be providing calculators), the shops in Budapest seem well stocked, with domestic goods at prices comparable with those abroad except that food is relatively inexpensive. These goods are exported at a special rate of exchange, however, that cuts their prices nearly in half (35 forints/dollar instead of 20), leaving Hungary in a more favorable position in regard to foreign exchange than other countries of the Soviet bloc. Wages have risen to the point where manual laborers now receive 3000 forints/month, graduate engineers 5000, and full professors 8000 with the possibility of considerably increasing this last figure through additional work. Still the wife is rare who stays home to look after her small children, even when her husband has a respected position.

Magyar Tudományos Akadémia Matematikai Kutató Intézete

At the Mathematical Institute wages tend to be lower than elsewhere (e.g., only 4500 forints/month for a senior research fellow, which can be augmented by extra activities) to offset the attractiveness of the working conditions. The Institute's employees are free to pursue whatever lines of research appeal to them. This freedom was part of the first director Alfréd Rényi's plan in founding the Institute in 1950, and after his death in 1971 his successor László Fejes Tóth has maintained this policy. (In Hungarian s



is pronounced *sh*, and *sz* is pronounced *ss* as in German.)

In addition to heading the Institute, Fejes Tóth [famous for his yellow Springer book *Lagerungen in der Ebene, auf der Kugel, und im Raum* (Packing in the Plane, on the Sphere, and in Space)] also heads its Geometry Group. His son Gábor works in the field of geometric inequalities, too, but he is found in the Information Theory Group in compliance with an antinepotism rule. The latter Group, headed by Dr. Imre Csiszár (the accents over Hungarian vowels indicate their sounds; the stress invariably falls on the first syllable), is one of the three "Stochastic Groups," the other two being Statistics, headed by Dr. István Vincze, and Probability, led by Pál Révesz. The other six Groups are: Combinatorics, Algebra, Differential Equations, Complex Analysis, the History of Mathematics, and the Teaching of Mathematics. Each Group includes about seven mathematicians.

The Institute receives about seventy visitors from abroad each year for periods ranging between a week and several months with the aid of the János Bolyai Mathematical Society (cf. ESN 31-6:229). The Society gets its funding from the sale of publications such as the proceedings of the 1975 Colloquium on Information Theory held 25-30 August in Keszthely, Hungary. This volume of 650 pages, edited by Imre Csiszár and Peter Elias (MIT), contains 41 papers presented at the Colloquium (excluding those destined for publication elsewhere), a quarter being by Hungarian authors. It is distributed by the North-Holland Publishing Company in Amsterdam and London, and its full table of contents appears on pages 6-7 of the December 1976 *Newsletter* of the IEEE Information Theory Group.

In addition to providing a source of income and much needed foreign currency, publications serve as a medium for barter to obtain foreign journals and books without having to apply for the precious foreign exchange that would otherwise be required. Thus, in the field of mathematics alone, not counting those in Hungarian, at least seven journals are published in Hungary, a country of ten million people.

For such a small country Hungary has certainly produced a very impressive number of outstanding mathematicians, and one is offered a variety of explanations. One of these credits Roland Eötvös, Minister of Education late in the nineteenth century, with having established a very

good system for education in science. Another attributes Hungarian preeminence to mathematical competitions in high school that began early in the twentieth century rather than to any unusual aspects of instruction; once identified, the superior students received individual attention from their teachers. Finally a third explanation notes that, on account of the lack of industrialization, Hungary could offer few jobs to its scientific graduates, and hence many have had to pursue their careers abroad, the best of them finding positions most easily. This explanation is sometimes augmented by observing that Hungary imposed quotas on the number of Jews allowed into medical schools, thus diverting some into a second, less highly regarded choice and thereby increasing the supply of mathematical talent. Perhaps the truth is a combination of all of these explanations and others.

Information Theory Group. Information Theory was first taught in Hungary by Rényi, who is well known for his generalization of Shannon's entropy. Later the information-theory course at the Eötvös Loránd Tudományegyetem (Roland Eötvös University of Science) in Budapest was taken over by Csiszár, who retains a half-time appointment there (like some of his colleagues) while working at the Mathematical Institute. It was through this course that Rényi got to know Csiszár and induced him to join the Institute, and Csiszár, in turn, brought in János Körner. [Körner's thesis, "A Property of Conditional Entropy," appears in *Studia Sci. Math. Hung.* 6, 355-359 (1971).]

Csiszár and Körner have, in fact, recently completed the first of two volumes on information theory à la Shannon, exploiting the power of "typical sequences" in obtaining exponential error bounds, etc. Volume I, dealing with the discrete case, is to be published by the Academic Press early in 1978; Volume II (on the continuous case) will appear at a much later date. This work is written in English in order to reach the largest possible audience, and its publication in the West can be credited to Eugene Lukacs, the recently retired famous probabilist who at one time headed the Statistics Branch of ONR and who has been an editor for the Academic Press. Csiszár, incidentally, has been elected to the Board of Governors of the IEEE Information Theory Group. With the aid of financial support from IBM, he and Körner (and perhaps K. Marton and P. Gács, as well) went to Ithaca, New York, to attend the 1977 IEEE International Symposium on Information Theory. Csiszár also attended the 1975

Symposium in Sweden.

The others in the Information Theory Group of the Mathematical Institute include József Beck, József Fritz, Katalin (Catherine) Marton, and Tibor Nemetz. (In Hungarian the family name always comes first, but I have given it last except in the names of streets and the Hungarian names of institutions, etc.) Miss Marton is a coauthor, along with Csiszár and Körner, of the paper "A New Look at Exponential Error Bounds for Memoryless Channels," dealing with universal codes, which was presented at the 1977 Cornell Information Theory Symposium. [These three are also collaborating on multiuser channels and correlated sources; see "General Broadcast Channels with Degraded Message Sets," *IEEE Trans. Information Theory* IT-23, 6-64 (Jan. 1977).] The other paper presented there was "Reliability Function for a Discrete Memoryless Channel at Rates above Capacity," by Körner.

Nemetz is studying the applications of information theory to statistics (a topic on which Csiszár and others formerly worked), bounding error probabilities in terms of information measures and their generalizations (such as f-divergences, where $-x \log x$ is replaced by an arbitrary convex function, as introduced by Csiszár in 1963), which describe the dissimilarity of statistical hypotheses. In this work Nemetz has the collaboration of L. Györfi of the Telecommunication Electronics Institute, who has also investigated the nonparametric estimation of the posterior probabilities of single statistical hypotheses. In addition, Nemetz has worked on optimum source coding and on the determination of the entropy rate of printed Hungarian, making use of his own improvements upon the method described in Shannon's 1951 *BSTJ* paper. These improvements aim at overcoming the effects of the high-school-student guessers' tiring after 100 letters and at avoiding the entropy-rate underestimation that would result from considering only the record of the best of the guessers for each passage, which may represent only a statistical fluctuation.

Fritz works on statistical physics and on random fields. He is concerned with finding out why, for example, the entropy is maximized by the Gibbs distribution of states, thus extending the work of Rényi on Markov chains and the work of Linnik.

Beck is young and has been at the Institute only two

years, devoting his attention to combinatorics and graph theory. In addition, for a memoryless channel with an abstract alphabet (of infinite size), Beck has obtained a lower bound for the error probability when transmitting above the channel capacity. He has generalized Stein's lemma on hypothesis testing, by which the Kullback-Leibler divergence gives the exponent of the error probability, and he has shown this to be independent of the distribution.

Several Mathematical Institute people in other Groups occasionally devote their attention to information-theoretical problems. One of these is Péter Gács, who works on complexity theory. Another is Gábor Tusnády, of the Statistics Group, who collaborated some time ago with Csiszár and Gyula Katona of the Combinatorics Group on "Information Sources with Different Cost Scales and the Principle of Conservation of Entropy" [*Zeitschrift für Wahrscheinlichkeitstheorie und verwandte Gebiete* 12 185-222 (1969)]. In collaboration with Nemetz, Katona published "Huffman Codes and Self-Information" in the May 1976 *IEEE Transactions on Information Theory*, showing that the code length for a symbol of probability $p << 1$ does not exceed $1.44 \log_2 p^{-1}$. Katona, who got his PhD at the Roland Eötvös University of Science in 1969, had earlier been a research fellow at the Telecommunications Research Institute, and he spent a semester at Chapel Hill, North Carolina, in 1969. In 1975 he was a visiting professor at Göttingen, West Germany.

It thus seems that in recent years Hungary has been reestablishing contact with the West. Indeed, among the honorary members of the Hungarian Academy of Sciences' Section on Mathematical and Physical Sciences are G. Pólya and G. Szegő of Stanford University and D. Gábor of Imperial College, London. Another sort of cross-fertilization is missing, however, in the modus operandi of the Mathematical Institute, as all those in the Information Theory Group are mathematicians by training, and there are no engineers to introduce a practical point of view, though informal contacts exist with engineers located elsewhere.

Much good work has nevertheless been done at the Institute, as mentioned above. Another example is "Source Coding with Side Information and a Converse for Degraded Broadcast Channels," by R.F. Ahlswede (formerly Ohio State Univ. and now at the University of Göttingen) and Körner (*IEEE Trans. Inform. Theory*, IT-21, 629-637, Nov. 1975). In addition to the

collaboration of Prof. Giuseppe Longo (Univ. of Trieste; *ESN* 31-6:229) with Körner and Csiszár, it is worthwhile to mention Körner's 52-page paper "Some Methods in Multi-User Communication: A Tutorial Survey," which was presented as part of the 1975 summer course on "Information Theory: New Trends and Open Problems" organized in Udine, Italy, by Longo. The proceedings of the course have been published by the Springer-Verlag. This paper includes 43 references, 13 being Hungarian work and the great majority of the others American.

To indicate the range of Csiszár's interests, a few of his papers of the last several years may be mentioned. "A Class of Measures of Informativity of Observation Channels," [*Periodica Mathematica Hungarica* 2, 191-213 (1972)] making use of f-divergences, was written while Csiszár was a visiting professor at the Catholic University of America. "On the Capacity of Noisy Channels with Arbitrary Signal Costs" appeared in *Problems of Control and Information Theory* 2, 283-304 (1973), continuing the work mentioned earlier by Csiszár, Katona, and Tusnády, and including the effects of feedback; this journal is published jointly by the USSR and Hungarian Academies of Sciences. The Mathematical Institute's quarterly *Studia Scientiarum Mathematicarum Hungarica* 9 (1974), 57-71, published Csiszár's paper "On an Extremum Problem of Information Theory," generalizing some finite-alphabet source-coding results to the case of an abstract (infinite) alphabet and thus covering continuous sources, where the "alphabet" is a function space. In "I-Divergence Geometry of Probability Distributions and Minimization Problems" [*Annals of Probability* 3 (1975), 146-158] he minimized the Kullback-Leibler divergence of a probability distribution under linear constraints (i.e., with given marginals or given generalized moments) without the use of Lagrange multipliers.

With Balram S. Rajput (Univ. of Tennessee) Csiszár published "A Convergence-of-Types Theorem for Probability Measures on Topological Vector Spaces with Applications to Stable Laws" [*Z. Wahrscheinlichkeitstheorie verw. Gebiete* 36, 1-7 (1976)], and with Körner he wrote "Source Networks with Unauthorized Users" [*J. Combinatorics, Information and System Sciences* 1, 25-40 (1976)], which considers separate coding of the output of each of two correlated sources. One source is treated as a "helper," and its coded form is made available to the destination in order to reduce the information rate required for coding the other source. The authors found

that (regardless of the coding of the helper) the latter rate is independent of whether the user knows the coding of the helper or he does not (his use of the helper is "unauthorized"); however, the coding required for the other source is more complicated in that case. Among the references cited in this paper is "Broadcast Channel with Confidential Messages," which the same authors have submitted to the *IEEE Transactions on Information Theory*, dealing with the transmission of messages to both destinations and to each, with each left entirely unenlightened concerning the confidential message sent to the other.

Statistics Group. Vincze, head of the Statistics Group of the Mathematical Institute, is also a part-time professor at the University. In Hungary the universities award a diploma after five years of study, plus a thesis and examination, and they also offer a doctorate (the "candidate" degree). But there is a still higher advanced degree, e.g., doctor of mathematical sciences (DMS), that is conferred later after some years of research and the submission of a dissertation to an institution affiliated with the Academy of Sciences. Corresponding members of the Academy are selected from among these higher doctorates, of which Hungary has about 100 in mathematical sciences as well as several hundred candidates (PhD's) in this field. *Vincze began his career with the geometry of curves, moving* then to applied statistics, and his 1969 DMS dissertation dealt with order statistics. In 1971 he published a book in German on statistics with industrial applications, and in 1974, along with Károly Sarkadi (a member of his Group), he published *Mathematical Methods of Statistical Quality Control* through the Academic Press.

Other members of his Group are Péter Major, Gábor Székely, Endre Csáki, Gábor Tusnády, and either Antónia L. Földes or Lídia Sz. Retô—two ladies working together although one of them is in the Probability Group. Csáki has published "An Investigation of the Empirical Distribution Function" in Hungarian (with 109 references) in *Osztely Közleményi* 23, 239-327, (1977) and Tusnády has recently written "Maximum-Likelihood Fitting of Multifactorial Threshold Models" along with L. Telegdi of the Computer and Automation Institute of the Hungarian Academy of Sciences in Budapest. The analysis of the data for a common isolated congenital malformation in Hungary led to this paper's modification of the Gauss additive multifactorial threshold model, which is formulated in terms of the covariance matrix calculated

by the method of R.A. Fisher and C. Smith.

Vincze has taught in Bahía Blanca, Argentina, in Magdeburg, East Germany, and in China in 1959 during the Sino-Soviet entente. In addition to his many statistical papers, he has published several in the field of information theory. At the 1959 Prague Conference on Information Theory and Statistical Decision Theory he presented "An Interpretation of the [Kullback-Leibler] I-Divergence of Information Theory," and in 1967 "Some Questions Concerning the Probabilistic Concept of Information" appeared in *IMS and AMS Selected Translations in Mathematical Statistics and Probability* (vol. 5). At the 1967 Debrecen (Hungary) Colloquium on Information Theory (pp. 503-509) he presented a paper "On the Information-Theoretical Foundation of Mathematical Statistics" extending Rényi's error-probability bounds to the case of a continuous distribution by dividing the domain of the estimated parameter into a set of intervals. Finally, his paper at the 1972 European Meeting of Statisticians in Budapest (pp. 869-893) was "On the Maximum Probability Principle in Statistical Physics," dealing with the extension to continuous distributions of results of Planck, Boltzmann, et al. By maximizing a pseudoprobability instead of the entropy as Jaynes did, he obtained modified forms of Bose-Einstein and Fermi-Dirac distributions.

Technical University of Budapest

With 1700 faculty members and well over 10,000 students, the Budapesti Műszaki Egyetem is by far the largest institution of university standing in Hungary. Its Faculty of Electrical Engineering has a staff exceeding 400 and a student body of over 3000, who are spread among a variety of entities. Each student is enrolled in one of four Divisions: Heavy Current, Electrical Instrumentation, Electronic Technology, or Telecommunication; while the faculty is grouped in a different manner, viz., into two Institutes (Heavy-Current Engineering and Communication Electronics) plus eight Chairs: Electromagnetic Theory (Gy. Fodor), Microwave Techniques (L. Pásztorniczky), Electronic Devices (I. Valkó), Electronic Engineering (I. Nágy), Automation (F. Csáki, recently deceased), Process Control (A. Frigyes), Electrical Instruments (L. Schnell), and Mathematics (T. Frey). Each Faculty has its own Chair of Mathematics.

Communication Electronics Institute. Professor Sandor Csibi heads the Institute for Communication Electronics,

which consists of six Departments: Computers, Circuits, Broadcasting, Telephone Exchanges, Wire Transmission and Data Processing, and Acoustics. Within the Division of Telecommunications, on the other hand, the students receive instruction from five Branches: Computers (mainly hardware), Broadcasting, Wired Telecommunication (including data teleprocessing), Microwave Techniques, and Semiconductor Devices and Microelectronics. Approximately 200 students of telecommunication enter the five-year diploma program each year.

Until recently Csibi had worked at the Telecommunication Research Institute (TKI), which is concerned primarily with the development of microwave telephone relay system designs and prototypes. In addition, Csibi worked there on automatic pattern recognition for abnormalities in electroencephalograms, and he brought this interest as well as some of the TKI personnel along to the Institute for Communication Electronics.

One of Csibi's papers concerns "Learning under Computational Constraints from Weakly Dependent Samples" [*Problems of Control and Information Theory* 4, 3-21 (1975)]. The sequence of samples is assumed to be Markov of order m, and consistent estimates of classification are nevertheless obtained. Csibi presented further work along this line at the 1975 Colloquium on Topics in Information Theory (pp. 143-153) held in Keszthely, Hungary, showing that, for indicators, the best approximation in the mean-squared-error sense also minimizes the probability of misclassification. Unfortunately my visit with Csibi turned out to be too short to permit me to learn of any of his more recent work, but there is also the possibiilty of some reluctance to release the latest Hungarian research, even though it may already have been submitted to a Western journal, as I observed this phenomenon at the Mathematical Institute. From his questions and comments on my own talk at his Institute concerning the output signal and noise from a nonlinearity, I nevertheless gained the impression that Csibi's interests are very broad.

Wire-Communication Department. Each of the six Departments in Csibi's Institute has a staff of the order of a dozen or 15 and is headed by an associate professor. Dr. Géza Gordos is in charge of the Department of Wire Communication and Data Processing. He got his telecommunicatons diploma from the Technical University of Budapest in 1960, specializing in filters, and he then went to work for the Post Office

Research Institute, where Denis Gábor and George von Békésy had once worked. It was there that Gordos became interested in signal-and-noise problems. He also developed an improved approach to the loading of frequency-divison-multiplex (FDM) relays as used, for example, in the USSR, where many different channels may be carrying the same facsimile signal (an on-off-keyed tone) to different towns for use in producing their local newspapers. The usual approach to loading based on independent signals in the channels would not be applicable; it would lead to overloading and, hence to distortion.

Although now teaching at the Technical University, Gordos is a consultant to Budavox, a Hungarian telephone manufacturer, for whom he was to travel to Pushchino, USSR, to discuss his work on the loading of telephone multiplex equipment. For the Budavox Company Gordos had developed a generator of a random waveform resembling human speech not only in its spectrum but also in its probability density function. For this purpose the noise generator includes a piecewise-linear circuit as well as a filter, and account is taken of its effect on the output spectrum.

The USSR is buying all of the telephone equipment it can get from Budavox, and it is even offering to finance plant expansion. The USSR's telephone needs are so great that it is procuring equipment wherever it be obtained, e.g., from the Nokia Company in Finland and Plessey in England. Gordos has spent some time in England on two different occasions (Imperial College in 1975 and Salford Univ. in 1974) and also Japan (in July 1977). He would like to visit the US if an invitation should be extended to him.

Gordos has written two books on filters based on his former teachers' lectures and a 207-page book on statistical communication theory published in 1969, all in Hungarian. He has translated the 1968 book *Principles of Data Communication*, by Lucky, Salz, and Weldon, into Hungarian, and in 1971 he wrote an often reprinted book on data transmission and data processing (DP) with chapters on information theory, coding, statistical communication theory, digital transmission, DP hardware, and DP software, the penultimate chapter having been written by Varga András.

Gordos has contributed chapters on communication theory and on information theory to various books, and

one of these led to a project, now terminated, apparently without much success, that sought to categorize babies' cries automatically into "dirty," "hungry," "angry," and "vocalizing." A related project, carried out by his students with the aid of a PDP-11 computer, attempted to distinguish between identical and fraternal twins by analysis of records of their voices. Twins between the ages 16 and 60 were recorded while reading the same newspaper, and it was found that the identical twins could be distinguished by the silences preceding their explosive sounds, which are evidently hereditary. Gordos feels that the phase spectrum may be determinative for this identification problem.

Computing Facilities. The Technical University seems to be well supplied with computers, there being an R-5 and an R-10 made in Hungary located in Csibi's Institute. Elsewhere on the campus is an IBM 370-115, installed in May 1977, that is to be equipped with three time-sharing terminals. There is also a 12-year-old transistorized (discrete-component) Razdan computer from Armenia, and there is an R-32 (resembling an IBM 360) that was produced in Poland. I was not able to see any of these machines because of the brevity of my visit to the Technical University, which was hastily arranged as a result of my talk (on the output signal and noise from a nonlinearity) at the Mathematical Institute so that I might present a similar talk to a more appropriate audience.

Other Institutions

In connection with the Telecommunications Research Institute (TKI), I have already mentioned Katona and Csibi, who worked there in the past. While visiting the Technical University I met András Baranyi, who is currently working at the TKI. His current interest is in the effect of two nonlinearities separated by a filter upon an FM waveform. The filter removes a large part of the harmonics produced in the first nonlinearity (e.g., an amplifier delivering the greatest possible fundamental output power), and the second one might be designed to remove the remainder of the contaminating harmonics. However, Baranyi finds that the delay introduced by the filter makes it impossible to do this by means of a memoryless nonlinearity. Possibly this problem arising in FDM-FM microwave telephone relaying might better be attributed to the filter's shifting the phases of the harmonics so that the resulting waveform cannot be regarded as having been produced by a memoryless

nonlinearity, and hence there is no inverse nonlinearity that will undo its effect.

While visiting the Mathematical Institute, I met some people from other organizations, among them Dr. Ivan Schmideg from the Fine Mechanical Works (FMV) and Dr. József Dénes of the Coordination Institute for Computing Techniques in Budapest. Dénes's paper on groupoids and codes is included in the proceedings of the 1975 Keszthely Colloquium mentioned earlier. Along with A.D. Keedwell he is the author of a book on *Latin Squares and their Applicatons* published in 1974 by the Academic Press, which is apparently now out of print except in Hungary; there it is available at the bookstore of the Hungarian Academy of Sciences on Vaci Utca, Budapest, for 320 forints.

Another book that may be mentioned in connection with information theory in Hungary is *On Measures of Information and their Characterizations*, by J. Aczél (University of Waterloo, Ontario) and Z. Daróczy (Math. Dep't., Kossuth Univ., Debrecen, Hungary), published in 1975 by the Academic Press. A review by Csiszár of this book appears in the November 1976 *IEEE Trans. Inform. Theory* (pp. 765-766). Daróczy's primary interest, however, appears to lie in the functional equations arising in this connection rather than in information theory and its applications.

Although Schmideg's present task is the simulation of the heat flow in a cabinet containing a microwave transmitter, I was particularly glad to meet him, as I had made use of his "Note on the Evaluation of Fourier Coefficients of Power-Law Devices" [*Proc. IEEE* 56 (Aug. 1968), 1383-1384] in determining what nonlinearity will have a prescribed effect on any given harmonic of a sinusoid, as a function of the amplitude of its input [*IEEE Trans. Inform. Theory* IT-17, 398-404 (July 1971)]. This work represents a part of Schmideg's doctoral dissertation, which has apparently not found other application apart from his papers "The Effects of Limiting on Angle- and Amplitude-Modulated Signal" [*Proc. IEEE* 57, 1302-1303 (July 1969)] and "Harmonic Synchronization of Nonlinear Oscillators" [*Proc. IEEE* 59, 1250-1251 (Aug 1971]. In 1968 and 1969 Schmideg was employed by the Microwave Laboratory of the Orion Radio and TV Works in Budapest, but by 1971 he was with the Institute for Electric Power Research, Budapest.

One result found in his thesis that he has still not published but which may be useful is the following.

For the amplitude $V_m(a)$ of the mth-harmonic output of a memoryless nonlinearity with a sinusoidal input of amplitude a, we have

$$(d/da)^m [a^m V_m(a)] = \sum_{r=0}^{m} K_{m,r}\, a^r (d/da)^r V_i(a),$$

where $K_{m,r}$ is an integer calculated from the λ_m coefficients in Schmidt's 1968 paper, and i is 0 or 1 accordingly as m is even or odd.

It may be mentioned that Hungary has two television networks, but people living near the Austrian border are able to receive TV from outside the curtain, which is there relatively transparent. In Eastern Europe the band from 63 to 74 MHz was selected instead of frequencies above 88 MHz for FM broadcasting, but this effort at isolation has had very little effect, as the medium-wave band (550-1600 kHz) easily carries programs across borders, especially at night, and short-wave receivers are not uncommon.

When officially invited, visitors are very warmly welcomed in Hungary, where they find no difficulty communicating in English with fellow research scientists and engineers. In many but not all other cases, however, the ability to speak German can be very useful. Some Hungarians seem much braver than others about showing sympathy toward representatives of Western governments, and so the visitor will find himself described as coming from a nongovernmental institution if his Hungarian hosts can possibly manage to do so. While the visitor should not conceal his affiliations, he should avoid embarrassing people by bringing them up unnecessarily. Despite many difficulties, however, Hungary seems to be keeping abreast of research in the rest of the world.